Chlorophyll concentration (Chl; micrograms per liter), nutrient concentration (μM), and nutrient ratios (by atoms) from lakes and depths (meters) where nutrient bioassay experiments were conducted

Lake	Depth	Chl	Nitrate	Nitrite	Ammonium	DIN	SRP	DIN:SRP
Bonney (east)	5	1.42	4.74	0.06	0.65	5.45	0.10	54.50
	13	1.20	21.54	0.19	0.86	22.50	0.19	118.90
	18	0.33	55.94	0.94	14.37	71.25	0.10	712.50
Bonney (west)	5	1.42	7.69	0.13	0.82	8.64	0.18	48.00
	13	6.23	30.13	0.21	0.71	31.05	0.14	221.79
Hoare	5	1.63	0.01	0.01	0.00	0.02	0.54	0.04
Fryxell	5	5.79	0.01	0.02	0.08	0.11	0.64	0.17

measurement (24 hours) to 120 hours. It should be noted that, owing to helicopter logistics, the sample collected at Lake Vanda remained in the dark for more than 10 hours in the collection carboy before processing. Together, these facts imply that the phytoplankton suffered physiological damage during sample storage. Consequently, bioassay results from Lake Vanda should be treated as suspect. The DIN:SRP ratios (table), however, indicate that Lake Vanda was phosphorus deficient, at least to the extent that one can assume that the nitrogen and phosphorus pools have similar turnover times.

These nutrient bioassay experiments are the first to address directly nutrient deficiency in lakes of the McMurdo Dry Valleys. To obtain a more thorough view of nutrient deficiency in these lakes, temporal experiments should be conducted over the phytoplankton growing season and should include samples from the phytoplankton maxima within each lake.

I thank Richard Bartlett, Cristopher Woolston, Vann Kalbach, and Rob Edwards for field and laboratory assistance. This research was supported by National Science Foundation grants OPP 91-17907 and OPP 92-11773 to J.C. Priscu.

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McMurdo LTER: Primary production model of benthic microbial mats in Lake Hoare, Antarctica

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Microbial mats are found throughout much of the benthic regions of antarctic lakes and streams and are composed primarily of cyanobacteria (e.g., *Phormidium, Oscillatoria,* and *Lyngbya*), pennate diatoms, and eubacteria (Vincent 1988). The perennially ice-covered lakes of Taylor Valley, southern Victoria Land, Antarctica, have well-developed benthic microbial communities (Wharton, Parker, and Simmons 1983). In places, portions of these mats tear loose (liftoff) from the sediments and float to the surface, where they are frozen within the overlying ice. This material is transferred through the ice by ablation and distributed by wind throughout the valley (Parker et al. 1982). The extremely low productivities of terrestrial ecosystems in this region suggest that allochthonous inputs of microbial mat may be an important source of the organic carbon found in soils. For these reasons, primary production of benthic mats is being investigated as an initial step in elucidating sources of organic matter and patterns of productivity in the Taylor Valley landscape.

A mathematical model was developed to examine the productivity patterns of benthic microbial mats in Lake Hoare, Taylor Valley, Antarctica (figure 1). Previous studies of algal production in antarctic streams and lakes suggest that primary production can be estimated with the equation for a rectangular hyperbola, driven by light intensity (Priddle 1980a,b; Howard-Williams and Vincent 1989):

$$P_n=\alpha/[1+(ß/I)] \qquad (1)$$

where P_n is hourly net primary productivity,

α is the maximum observed production rate [28.89 milligrams of carbon per square meter per hour (mg C m^{-2} hr^{-1})],

I is the average hourly sunlight intensity [microeinsteins per second per square meter (μE s^{-1} m^{-2})] incident to the algae, and

ß is the half-saturation coefficient (2.23 μE s^{-1} m^{-2}). Model parameters are derived from the detailed investigations of *Phormidium spp.* mats in Signy Island lakes (Priddle 1980a,b) and Taylor Valley streams (Howard-Williams and Vincent 1989).

A continuous, 1-year (1988–1989) light regime of average daily light intensities recorded immediately beneath the lake ice [approximately 10 percent incident photosynthetically available radiation (PAR)] was used to drive the model (figure 2). We assumed that light intensity diminished as a negative exponential function of depth (figure 3), given depth-specific light attenuation coefficients reported for Lake Hoare (Palmisano and Simmons 1987):

$$I=S\cdot e^{(-km)} \qquad (2)$$

where S is ambient sunlight intensity (μE s^{-1} m^{-2}) at the water surface immediately below the ice cover,

k is the light extinction coefficient (m^{-1}), and

m is water depth [in meters (m)].

Simulations were conducted over the 365-day interval for which sunlight data were available (figure 2). Total annual net primary productivity was estimated for mats at 1-m intervals from 0 to 15 m depth, driven by incident light intensity (equation 2), and assuming identical model parameters at all depths (equation 1).

Estimates of total annual net production varied from a maximum of 155 g C m^{-2} at just beneath the lake ice, to about 0.72 g C m^{-2} at a depth of about 15 m (figure 3). These values lie within reported levels of net annual production of benthic microbial communities in other antarctic streams and lakes at similar depths (table) and appear to be sufficient to supply quantities of mat materials that are estimated to be lost by liftoff and ablation from Lake Hoare (Parker et al. 1982).

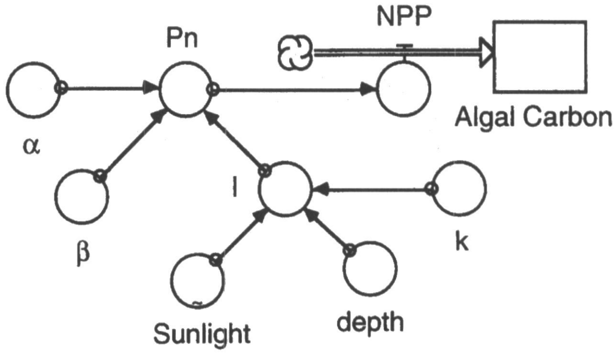

Figure 1. Flow diagram of net primary production (NPP) of benthic microbial mat in Lake Hoare, Antarctica.

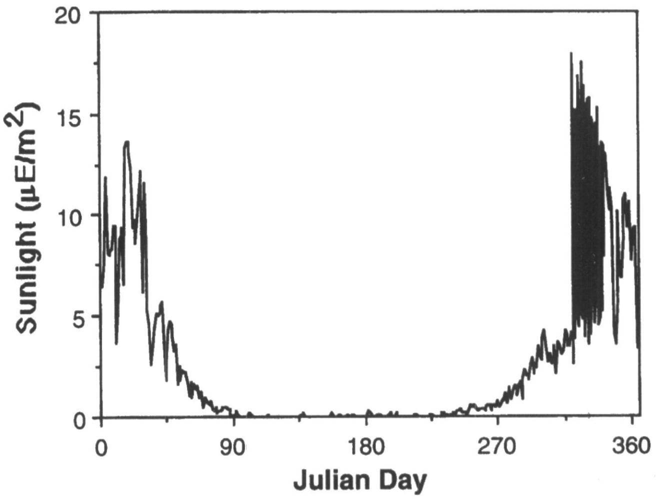

Figure 2. Daily average sunlight intensity immediately beneath the ice at Lake Hoare, Antarctica (1988–1989; Clow unpublished data).

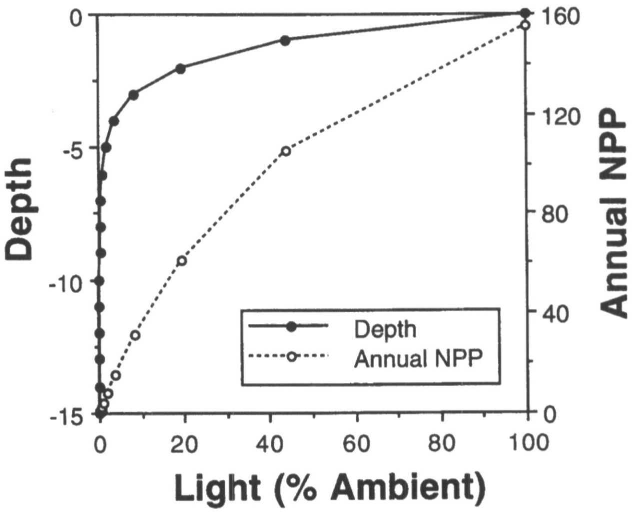

Figure 3. Depth-specific light intensity (as a percentage of recorded intensity; figure 2) and simulated annual net primary productivity (NPP) (g C m^{-2}) for Lake Hoare, Antarctica.

Wharton et al. (1983) report that the distribution of mats beneath the permanent ice cover in Lake Hoare ranges between 5 and 30 m depth, with the more productive communities (columnar liftoff mats) found to a depth of about 12–13 m. Our simulations suggest very low productivities at depths greater than 10–15 m (figure 3) and, although respiration rates have been incorporated in the estimated net primary productivity rates (equation 1), the form of this equa-

Production of benthic microbial mats in antarctic ponds and lakes (g C m^{-2} yr^{-1})

Primary production	Lake and location	Reference
11	Changing Lake; Signy Island	Priddle 1980b
45	Sombre Lake; Signy Island	Priddle 1980b
37	Fresh Pond; McMurdo Ice Shelf	Howard-Williams et al. 1989[a]
57	Skua Lake; McMurdo Ice Shelf	Howard-Williams et al. 1989[a]
60	Ice Ridge; McMurdo Ice Shelf	Howard-Williams et al. 1989[a]
36	P-70 Lake; McMurdo Ice Shelf	Howard-Williams et al. 1989[a]
39	Brack Pond; McMurdo Ice Shelf	Howard-Williams et al. 1989[a]
26	Salt Pond; McMurdo Ice Shelf	Howard-Williams et al. 1989[a]
140–230	Skua Lake; McMurdo Ice Shelf	Goldman, Mason, and Wood 1972
172–327	Algal Lake; McMurdo Ice Shelf	Goldman, Mason, and Wood 1972
5.5	Watts Lake; Vestfold Hills	Heath 1988
26	Lake Hoare; Taylor Valley	J.R. Vestal (unpublished data, 1988)
0–113	Lake Bonney; Taylor Valley	Parker and Wharton 1985

[a] Extrapolated over a 120-day season.

tion does not allow a negative production value estimate (i.e., respiration is greater than photosynthesis). Empirically determined photosynthetic and respiration rates for microbial mats are needed to develop a more realistic model that separately describes both processes. This would permit evaluating the conditions under which net losses and gains of carbon may occur. Such a model formulation also would permit calculating nutrient turnover, as well as incorporating nitrogen and phosphorus constraints on production.

This work was supported by National Science Foundation, grant OPP 92-11773.

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